(12) UK Patent Application (19) GB (11) 2 205 650 (13) A

(43) Application published 14 Dec 1988

(21) Application No 8800009

(22) Date of filing 4 Jan 1988

(30) Priority data
(31) 3715698 (32) 12 May 1987 (33) DE

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(51) INT CL[4]
G01B 7/03

(52) Domestic classification (Edition J):
G1N 1D13 7N AEB
G1M 11F 12C 12F FAA

(56) Documents cited
GB A 2020813 EP A2 0098551 US 4528758

(58) Field of search
G1N
G1M
Selected US specifications from IPC sub-classes
G01B G01D

(54) **Contact sensing probe**

(57) A probe for use in three dimensional measuring and marking machines comprises a contact member 15, 16 pivotally mounted in a housing 12 via changes 31, 32 and a leaf spring 24, together with a spring 40 acting along the direction of the member 15. A soft magnetic holder 37 on the inner end of member 15 carries three spaced magnets 22 in close proximity to corresponding magnetoresistors 21 mounted in the housing. The values of the resistors provide an indication of the direction and amount of deflection of the contact member along X, Y and Z coordinate directions, and may provide a switching signal.

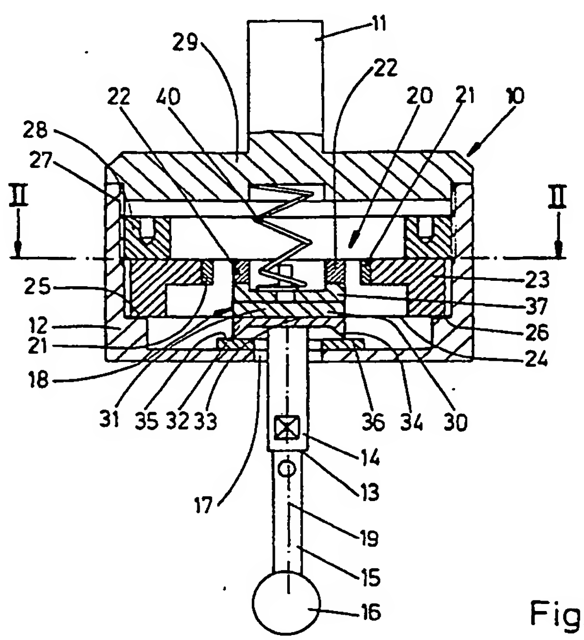

Fig.1

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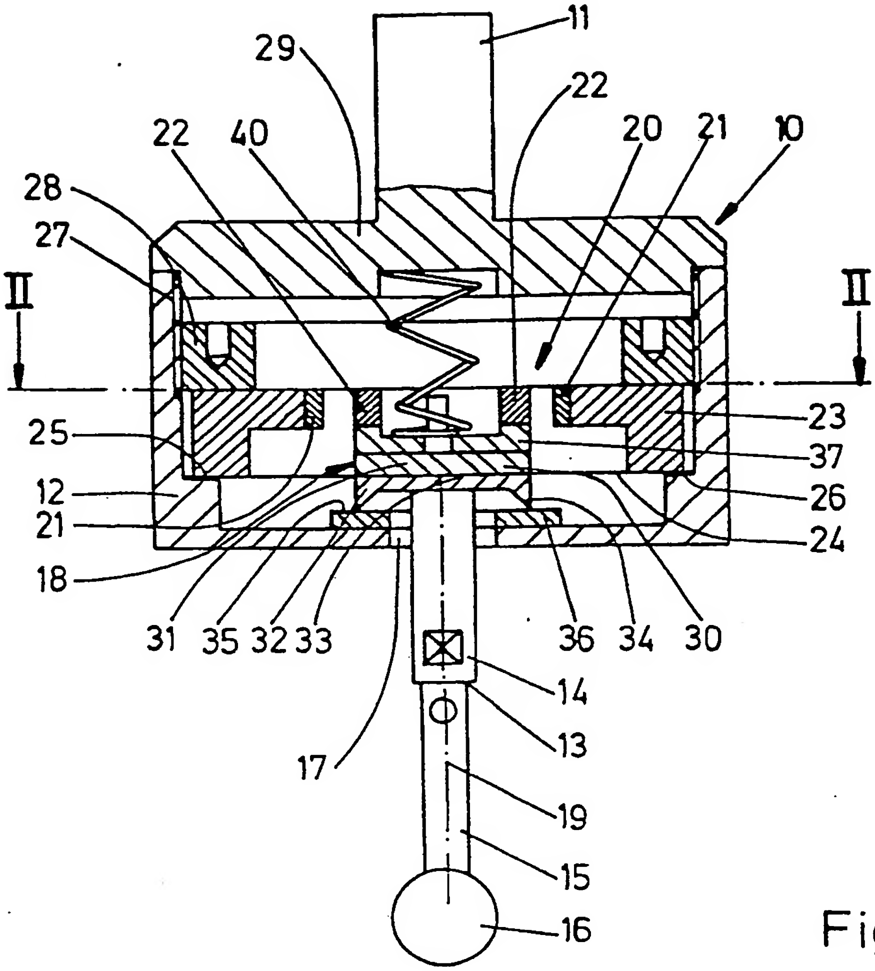
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Fig.1

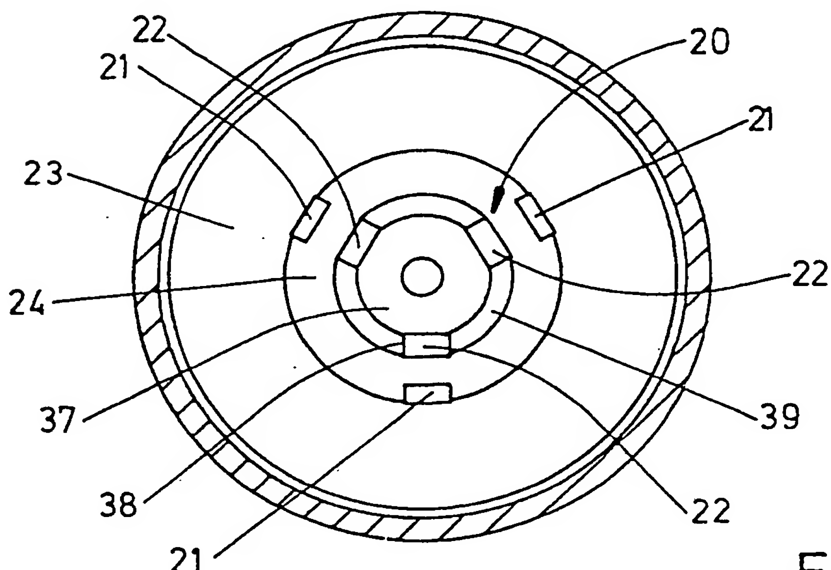
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Fig.2

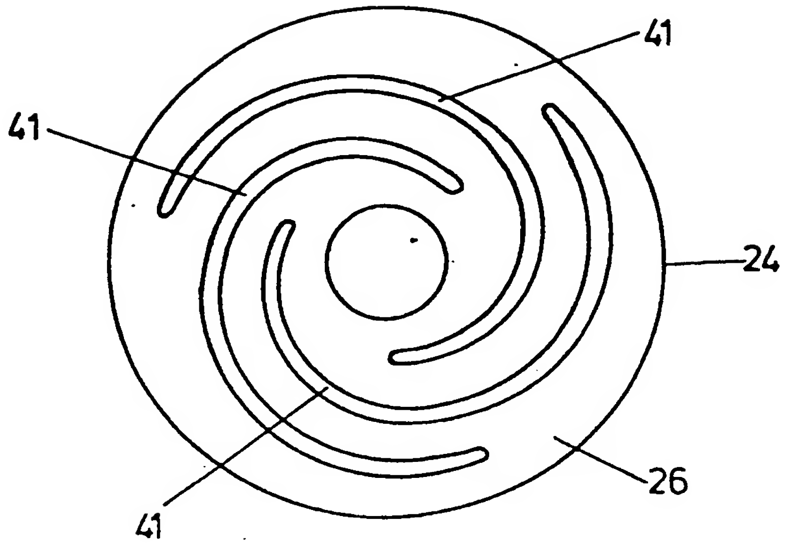

Fig.3

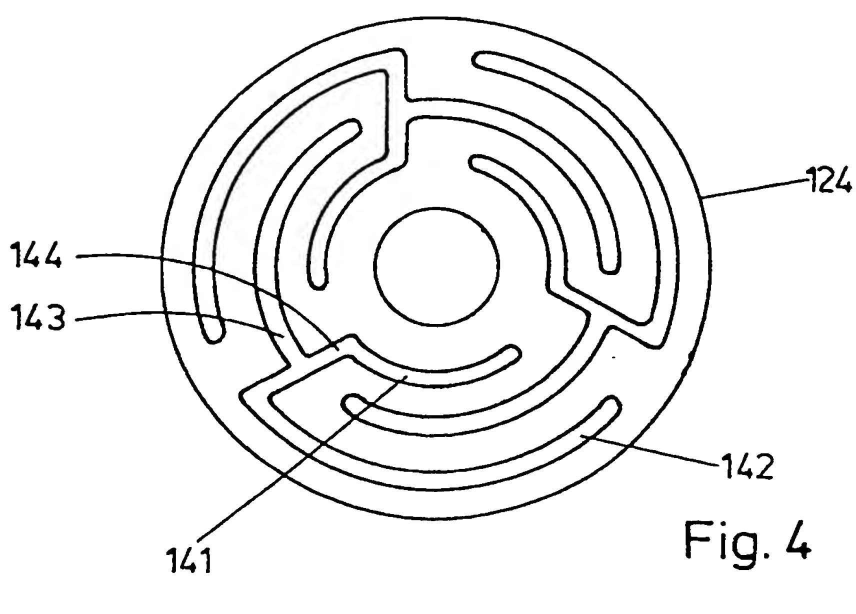

Fig. 4

TITLE: SENSING HEAD. 2205650

This invention relates to a sensing head for the three-dimensional sensing of test pieces, for three-dimensional measuring and/or marking machines comprising a sensing element, operating by contact, in a housing, in which the sensing element is movably mounted by means of at least one bearing device in the direction of the axes of a spatial coordinate system and in which a measuring device, operating without contact, is contained, by means of which measuring device the movement of the sensing element can be converted into an associated output signal.

A sensing head of this type is known (DE-OS 20 19 895), the measuring device of which operates inductively or capacitively without contact. Apart from the fact that such a sensing head cannot operate with sufficient sensitivity, this measuring device necessitates a bulky construction. It also requires large moving masses, with the result that large deformations occur at the sensing pin and in other moving components in an adverse manner. Furthermore, relatively large restoring forces are accordingly necessary as the sensing force decreases, and these restoring forces accordingly result in relatively large sensing forces with the disadvantages of increased bending of the sensing pin and other moving components

and also deformation of the surface of the measured object, especially when the latter is of relatively soft materials. In this sensing head of known type, furthermore, the problem is not solved of restoring the sensing pin, after the sensing force had decreased, into its starting position in a reproducible and rapid manner and also of making possible a sufficiently large excess stroke in the sensing pin direction.

An object of this invention is to create a sensing head which is small, light and compact as possible, comprises the minimum number of components and is simple to construct, the measuring device of which shall be simple, small and easy to procure and, even when small deflections of the sensing pin occur, shall operate very accurately and in a reproducible manner.

According to the invention there is provided a sensing head for the three-dimensional sensing of objects comprising

a) a housing

b) at least one bearing surface provided in said housing,

c) a sensing element movably mounted on said bearing surface and extending in part exteriorly of said housing for operation by contact with an object, said sensing element being movable along

the axes of a spatial coordinate system, and

d) a measuring device disposed within said housing for operation without mechanical contact, said measuring device serving as a transducer for converting movement of said sensing element into an associated electrical output signal, said measuring device including

e) a plurality of magnetic sensors fixedly mounted in said housing and being in the form of magnetically controllable resistors, and

f) antipoles carried by said sensing element and being spatially arranged in proximity to and associated with said magnetic sensors.

In this manner the measuring device may be extremely small, space-saving, light and inexpensive. It requires only small moving masses and has the advantage that with a small deflection of the sensing pin an extremely accurate measurement is possible. The prerequisites are created for constructing the sensing head either as a switching feeler or as a measuring feeler. By the measuring device, three measuring systems are integrated in the sensing head, which also have the advantage that they make possible a statement about the present direction of sensing. With the construction as a measuring feeler, scanning is also possible in an advantageous manner. Further details and advantages of this measuring device will become

apparent from the special description, to which attention is drawn in order to avoid unnecessary repetition.

Magneto-resistive elements as magnetically controllable resistors, especially semiconductor resistors, may be used which are especially simple as magnetic field-dependent components and are also inexpensive in this form.

Preferably the antipoles are disposed axially offset relative to the magnetic sensors towards the free end of the sensing element which projects out of the housing. This construction makes possible, by appropriate geometrical design of the magnetic sensors and the gap geometry, a defined force flux of the magnetic forces that occur, such that any spring restoring elements for the restoring of the sensing element, after the sensing force has died away, into the relevant starting position can become unnecessary. Furthermore, by appropriate determination or modification of the gap geometry between the antipoles and the sensors, especially magneto-resistive elements, the size of the force and thus the sensing force can be deliberately modified. Thus the requirement for a re-adjustable, adaptable restoring force can be met.

The magnetic sensors may be fixed in a preferably non-magnetic annular component which may be generally in the form of a leaf spring. By the leaf spring, a

highly accurate bearing device is created, which permits a large stroke, ensures exact reproducibility and also permits eccentric forces, such as those that occur when star feelers are used as a replaceable sensing insert. Because the leaf spring is rotationally symmetrical and acts in a rotationally symmetrical manner, the same behaviour is obtained when sensing around the entire periphery of the sensing head. The bearing device leads to good mechanical stability and reproducibility of the starting position in each case of the sensing element and to rapid restoration into the starting position with a small restoring force, so that during sensing also the effective sensing force is relatively small. This has the advantage that, when sensing objects of soft materials, the risk of some deformation is avoided and when objects having a hard surface are sensed the risk of deformation of the sensing pin, the replaceable sensing insert and the typically spherical sensor end is also avoided.

The antipoles are preferably seated on a generally pot-shaped holder, which is fixed on the clamping holder on the side of the leaf spring which is remote from the bearing ring. Due to the disposition of the magnetic sensors and associated antipoles an axial force component resets the sensing element so that a special restoring spring, acting axially for restoring

into the defined starting position, is rendered unnecessary.

The invention will now be described in greater detail by reference to examples of embodiment thereof shown in the accompanying drawings in which:-

FIGURE 1 is a schematic axial section with partial lateral view of a sensing head according to a first example of embodiment,

FIGURE 2 is a schematic section along the line II-II in Figure 1,

FIGURE 3 is a schematic, enlarged plan solely of the leaf spring of the sensing head in Figure 1,

FIGURE 4 is a schematic, enlarged plan of a leaf spring according to a second example of embodiment.

In Figures 1 to 3, a sensing head 10 according to a first form of embodiment is shown, which is intended for the three-dimensional touch-sensing of test pieces, not shown, and is seated for this purpose, for example by means of a schematically indicated fixing journal 11, in a tool seating of a three-dimensional measuring and/or marking machine, as explained, for instance, in DE-PS 17 73 282 or 17 98 419.

The sensing head 10 comprises, in a housing 12, a sensing element 13, which possesses a substantially bar-shaped portion 14 and a sensing insert 15, also

substantially bar-shaped and replaceably mounted on the former, this sensing insert having, for instance, a spherical sensing end 16. The sensing element 13 passes, by its portion 14, through an opening 17 of the housing 12 substantially larger than the element.

The sensing element 13 is mounted, movable in the direction of the axes of a spatial coordinate system, by means of a bearing device 18 in the housing 12, so that the sensing element 13 can be pushed in in the direction of the longitudinal central axis 19 into the housing 12 and also is pivotally movable in the region of the bearing device 18 about the longitudinal central axis 19.

In the housing 12, furthermore, a measuring device 20 acting without contact is contained, this device being active between the housing 12 on the one hand and sensing element 13 on the other hand when a relative movement between these two components occurs, by means of which (measuring device) such a relative movement, for example of the sensing element 13, can be converted into an associated output signal. The measuring device 20 comprises, on the one hand, a plurality of magnetic sensors 21 mounted fixed on the housing, which are here indicated only schematically. These magnetic sensors 21 are constructed as magnetically controllable resistors, especially semiconductor resistors, and are themselves of known type. They are formed in the

present case as magneto-resistive elements and are disposed on a circle at approximately equal angular intervals from one another. Another part of the measuring device 20 is constituted of antipoles 22 on the sensing element 13, associated with the sensors 21, which are disposed at a radial and/or axial distance from the sensors 21. The antipoles 22 are also disposed on a circle at generally equal angular intervals, this circle being an inner circle which is coaxial to that of the sensors 21 and is surrounded by the latter. The antipoles 22 are thus situated inside and the sensors 21 outside. In another example of embodiment, not shown, the conditions may be reversed. In the example of embodiment illustrated, there are three sensors 21 and associated antipoles 22. It will be understood that even fewer or, in particular, more of them may be provided. As Figure 1 shows, the magnetic sensors 21 and the associated antipoles 22 are located at the same axial height. It should be understood that in another example of embodiment, not shown, the antipoles 22 may be arranged at an axial distance from the sensors 21, for example nearer towards the free end of the sensing element 13 projecting out of the housing 12.

The sensors 21 are here indicated only schematically and in the form, for instance, of commercially obtainable magneto-resistive elements,

themselves known. The same is true also for the associated antipoles 22. The sensors 21 are fixed on a preferably non-magnetic annular component 23, which is fixed, axially and circumferentially immovable, in the pot-shaped housing 12. This annular component 23 is formed as an axial clamping component, which fulfils a clamping function also for the bearing device 18. The bearing device 18 comprises a generally annular leaf spring 24, relatively thin in cross-section, which forms a rotationally symmetrical bearing element for the sensing element 13, which is firmly connected with the leaf spring 24. The housing 12 contains, in its interior, a radially projecting shoulder 25, on which the leaf spring 24 bears with its outer edge 26. On the opposite side of the leaf spring 24 there is the annular component 23, by which the leaf spring 24 is pressed axially firmly onto the shoulder 25. The housing 12 is furnished internally at least over a portion of its length with an internal thread 27, into which a threaded ring 28 is screwed, which in Figure 1 presses downwards onto the annular component 23 and presses the latter firmly onto the leaf spring 24. The upper, open end of the pot-shaped housing 12 is closed by means of a lid 29, carrying the fixing journal 11.

The sensing element 13 comprises a clamping holder 30, coaxial with it, which consists of two parts 31 and 32, firmly clamped together, between which the leaf

spring 24 is centered and is firmly clamped in the region of its radially inward edge. The leaf spring 24 extends generally perpendicularly to the sensing element 13.

The sensing element 13 comprises a bearing ring 33 which, in the example shown, is formed in one piece with the clamping holder 30, that is with its one part 32. This bearing ring 33 is therefore located on that side of the leaf spring 24 which is towards the free end of the sensing element 13 projecting out of the housing 12. The bearing ring 33 is coaxial to the sensing element 13 and surrounds it with a radial gap. It comprises an axially projecting annular cutting edge 34, by which the bearing ring 33 bears axially on a seating surface 35, fixed in the housing, which is formed by the nearer face of a bearing plate 36. The bearing plate 36 is of a hardened material, so that an enduring, exact and hard seating surface 35 is assured.

On the side of the leaf spring 24 that is remote from the bearing ring 33, there is a holder 37, generally pot-shaped in cross-section, made from soft magnetic material. The holder 37 is firmly connected with the clamping holder 30. It is the carrier of the individual antipoles 22 which are disposed, for instance, in corresponding recesses 38 in the wall 39 of the holder 37.

Between the housing 12, that is its lid 29, and the

sensing element 13, in the example of embodiment shown there is a preferably adjustable compression spring 40, in the present case in the form of a cylindrical helical spring, by means of which the sensing element 13 can be axially restored and axially pressed by the annular cutting edge 34 onto the seating surface 35. The sensing head 10 is formed either as a switching feeler or as a measuring feeler. If it is constructed as a measuring feeler, the reading from each sensor 21 is fed, via electrical conductors not illustrated, to an electronic microprocessor, also not shown, which converts the three readings obtained in the deflection of the sensing element 13 into translatory coordinates of the spatial coordinate system, that is into X-, Y- and Z- coordinates. For the conversion the known geometrical data of the sensing head 10 are also fed to the microprocessor, especially those of the sensing element 13 and particularly of the sensing end 16. In this way the deflection of the sensing end 16 in the spatial coordinate system can be exactly calculated. These values are known and are utilized for the adjustment control of the individual machine axes and also for calculation with the X-, Y- and Z- values of the measuring machine for exact determination of the measured point.

Details of the leaf spring 24 are now explained by reference to Figure 3. The leaf spring 24 contains

several slit-shaped apertures 41, extending at least generally in the circumferential direction. In the example shown, a total of three such apertures 41 are present, each extending through about 270° angle of arc and being staggered circumferentially by about 120° and also being of general spiral shape. Due to the apertures 41 and this configuration and distribution, the most rotationally symmetrical behaviour possible of the leaf spring 24 is assured.

In the second example in Figure 4, which also shows a leaf spring 124, three groups each comprising three slit-shaped apertures 141, 142 and 143 are present instead. Each aperture 141 to 143 is arranged itself on a circle, these circles being concentric. Each aperture 141 to 143 extends through about 90°. The aperture 141, which is disposed on the smallest circular arc, and the aperture 142, which is on the largest circular arc and in the same sector, are connected together at one end by a slit 144, extending at least generally radially or along a secant. The aperture 143, on the central circular arc, extends from the slit 144 circumferentially away from the other two apertures 141, 142. Consequently, this slit-shaped aperture 143 on each occasion passes between two apertures 141, 142. Each group comprising these so constructed three apertures 141 to 143 thus has approximately the form of a two-pronged fork, curved

around a circle.

In one example of embodiment, differing from Figure 1 and not shown here, the compression spring 40 is absent, the magnetic sensors 21 and associated antipoles 22 being, instead, so arranged that the function of the compression spring 40 is undertaken by them and an axial force component of the magnetic forces resets the sensing element 13 axially and presses it by the annular cutting edge 34 onto the seating surface 35.

If, during sensing by means of the sensing head 10, the sensing element 13 is deflected against the action of the compression spring 40 and/or the leaf spring 24, which prevents a rotation of the sensing element 13 about the longitudinal central axis 19 and assures a resetting into the position according to Figure 1, then the bearing ring 33 by its annular cutting edge 34 lifts off to a greater or lesser extent from the seating surface 35 in one region, depending upon the direction of deflection and strength. The holder 37, firmly connected with the sensing element 13, is displaced out of the central position shown in Figure 1 with a corresponding change in the position of the antipoles 22. The movement of the holder 37 with the antipoles 22 leads to a change in resistance of the magnetic sensors 21, the resistance of the sensors 21 each being dependent upon the distance travelled by the

moved holder 37 with antipoles 22. The change in resistance that occurs at the sensors 21 is detected and evaluated by means of a suitable evaluating circuit, a pulse signal or a measured value representing the absolute distance of the relative movement being produced according to whether the sensing head 10 is constructed as a switching feeler or as a measuring feeler, which pulse signal or measured value can be processed by means of a connected evaluator circuit.

In the case of construction as a switching feeler, a switching point is electrically formed inside the measuring range, i.e. the functional dependence of the resistance of the sensors 21 upon the distance travelled by the holder 37 with antipoles 22. The relative position of the switching point with respect to the triggering point on contacting a sensed measured object can be varied, that is to say for example can be electrically adjusted.

The measuring device 20 of the type described furthermore has the advantage that by the magnetic forces that occur a defined force flux can be achieved by appropriate design of the sensors 21. By the relative arrangement of the sensors 21 and antipoles 22 to one another, a direction of this force can deliberately be produced, with the result that a spring resetting by means of the compression spring 40 can be

rendered unnecessary. Furthermore, by the change of the geometry of the gap between the sensors 21 and the antipoles 22, the size of the force and therefore the sensing force of the sensing head 10 can be deliberately modified. The requirement for a self-adjusting, re-adjustable restoring force can also thereby be satisfied.

The measuring device 20 is especially advantageous because where three sensors 21 with associated antipoles 22 are provided, it integrates three measuring systems in the sensing head 10. It is furthermore advantageous that the measuring device 20 makes possible information not only about the absolute distance moved but also about the direction of deflection and thus direction of sensing, which hitherto was not possible.

In the construction as a measuring feeler, scanning is also possible. By the described form of construction of the leaf spring 24, the following advantages are achieved. The leaf spring permits a large stroke, assures exact reproducibility and also permits eccentric forces such as, for example, occur in the use of star sensors. Overall, a highly accurate bearing element is created, which as before ensures that the sensing element 13 cannot rotate about its longitudinal central axis 19.

The restoring force that is provided, for instance,

by the compression spring 40 can be adapted by manual adjustment of the compression spring 40 to the particular circumstances, for example to whether the measured object is of a soft material which tends to deform when sensed or has a hard surface. The set switching point or the particular measured values are on each occasion reliably reproducible. Extremely easy deflection during sensing from any direction is possible and, when the sensing force dies away, a reproducible, equally good re-centering back into the starting position is also assured. This is due to the rotationally symmetrical behaviour around the entire circumference of the sensor.

It is furthermore advantageous that the masses of the components to be moved during sensing are as small as possible, which furthermore contributes also to a rapid and reproducible resetting into the starting position when the sensing force disappears. In general, the entire sensing head is small, light, simple to construct and inexpensive.

CLAIMS

1. A sensing head for the three-dimensional sensing of objects comprising

a) a housing (12),

b) at least one bearing surface (18) provided in said housing,

c) a sensing element (13) movably mounted on said bearing surface and extending in part exteriorly of said housing for operation by contact with an object, said sensing element being movable along the axes of a spatial coordinate system, and

d) a measuring device (20) disposed within said housing for operation without mechanical contact, said measuring device serving as a transducer for converting movement of said sensing element into an associated electrical output signal, said measuring device (20) including

e) a plurality of magnetic sensors (21) fixedly mounted in said housing and being in the form of magnetically controllable resistors, and

f) antipoles (22) carried by said sensing element and being spatially arranged in proximity to and associated with said magnetic sensors (21).

2. A sensing head according to Claim 1, wherein said antipoles (22) are spaced within said magnetic sensors (21) and radially therefrom.

3. A sensing head according to Claim 1, wherein said antipoles (22) are axially spaced from said magnetic sensors (21) considered longitudinally of said sensing head.

4. A sensing head according to Claim 1, wherein said antipoles (22) are spaced within said magnetic sensors (21) and radially therefrom, said antipoles (22) being also displaced axially from said magnetic sensors (21) considering longitudinally of said sensing head.

5. A sensing head according to Claim 1, wherein said magnetically controllable resistors are semiconductor resistors.

6. A sensing head according to any one of claims 1 to 5, wherein magnetic sensors (21) and the associated antipoles (22) are each disposed on a circle and at approximately equal angular distances from one another.

7. A sensing head according to any one of claims 1 to 6, wherein there are provided at least three magnetic sensors (21) and associated antipoles (22).

8. A sensing head according to any one of claims 1 to 7, wherein the magnetic sensors (21) are disposed on an outer circle surrounding the antipoles (22) and outside.

9. A sensing head according to any one of claims 1 to 8, wherein the magnetic sensors (21) and the associated antipoles (22) are disposed at equal axial

height.

10. A sensing head according to any one of claims 1 to 9, wherein the antipoles (22) are disposed axially offset relative to the magnetic sensors (21) towards the free end of the sensing element (13) which projects out of the housing (12).

11. A sensing head according to any one of claims 1 to 10, wherein the magnetic sensors (21) are fixed on a non-magnetic annular component (23), which is mounted immovably axially and circumferentially in the housing (12).

12. A sensing head according to Claim 11, wherein the annular component (23) is constructed as an axial clamping component, by means of which a generally annular leaf spring (24) is firmly clamped immovably axially and circumferentially on the housing (12).

13. A sensing head according to Claim 12, wherein the housing (12) has a radially projecting shoulder (25), upon which the leaf spring (24) bears at its edge.

14. A sensing head according to Claim 12 or 13, wherein the annular component (23) is pressed against the leaf spring (24) by means of an axially adjacent threaded ring (28) pressing onto it.

15. A sensing head according to Claim 12, 13 or 14, wherein the leaf spring (24) extends generally perpendicularly to the sensing element (13), is of

general annular shape, and is connected, in the region of its radially inward edge, firmly with the sensing element (13) passing through it.

16. A sensing head according to Claim 15, wherein the sensing element (13) possesses a clamping holder (30), between which the leaf spring (24) is firmly clamped.

17. A sensing head according to any one of claims 12 to 16, wherein the leaf spring (24; 124) contains a plurality of slit-shaped apertures (41; 141 - 143) extending at least in general circumferentially.

18. A sensing head according to Claim 17, wherein there are provided three slit-shaped apertures (41), which each extend through about 270° circumferential angle, are staggered circumferentially by about 120° from one another and are each generally of spiral shape.

19. A sensing head according to Claim 17, wherein there are provided three groups each comprising three slit-shaped apertures (141 - 143), which are each disposed upon mutually concentric circles and each extend through about 90° circumferential angle, the aperture (141) on the smallest circular arc and the aperture (142) on the largest circular arc being disposed in the same sector and being connected together at one end by a slit (144) running generally radially or along a secant, and the aperture (143) on

the central circular arc extending from the slit (144) in the circumferential direction opposite to that of the other two apertures (141, 142).

20. A sensing head according to any one of claims 1 to 19, wherein the sensing element (13) possesses a coaxial bearing ring (33) surrounding it at a distance and having an axially projecting annular cutting edge (34), by which the bearing ring (33) sits axially upon a seating surface (35) fixed to the housing (12).

21. A sensing head according to Claim 20, wherein said seating surface is a hardened bearing plate (36).

22. A sensing head according to Claim 12, wherein the sensing element possesses a coaxial bearing ring (33) surrounding it at a distance and having an axially projecting annular cutting edge (34), by which the bearing ring (33) sits axially upon a seating surface (35) fixed to the housing, said bearing ring (33) being disposed on the side of the leaf spring (24) which faces towards the free end of the sensing element (13) projecting out of the housing (12).

23. A sensing head according to Claim 22, wherein the sensing element possesses a clamping holder (30), between which the leaf spring (24) is firmly clamped, said bearing ring (33) being constructed as a part of the clamping holder (30).

24. A sensing head according to Claim 23, wherein the antipoles are seated on a generally pot-shaped

holder (37), which is fixed on the clamping holder (30) on the side of the leaf spring (24) which is remote from the bearing ring (33).

25. A sensing head according to Claim 24, wherein the generally pot-shaped holder (37) possesses apertures (38) in its wall (39), in which the antipoles (22) are disposed.

26. A sensing head according to Claim 24, wherein the holder (37) is made of soft magnetic material.

27. A sensing head according to Claim 20, wherein there is provided a coaxial compression spring (40) between the housing (12) and the sensing element (13), by means of which the sensing element can be axially reset and axially pressed with the bearing ring (33), especially its annular cutting edge (34), against the seating surface (35).

28. A sensing head according to Claim 20, wherein the magnetic sensors (21) and associated antipoles (22) are so arranged that an axial force component of the magnetic forces axially resets the sensing element (13) and presses it with the bearing ring (33), especially its annular cutting edge (34), onto the seating surface (35).

29. A sensing head substantially as described with reference to the accompanying drawings.

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